ESD-TR-88-262 MTR-10330

Application of Modular Building Block Databus to Air Force Systems — Final Report

By

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June 1988

Prepared for

Deputy Commander for Advanced Decision Systems
Electronic Systems Division
Air Force Systems Command
United States Air Force
Hanscom Air Force Base, Massachusetts

Project No. 6250

Prepared by

The MITRE Corporation
Bedford, Massachusetts

Contract No. F19628-86-C-0001

Approved for public release; distribution unlimited.

REVIEW AND APPROVAL

This technical report has been reviewed and is approved for publication.

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UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION
Unclassified

1b. RESTRICTIVE MARKINGS

2a. SECURITY CLASSIFICATION AUTHORITY

2b. DECLASSIFICATION / DOWNGRADING SCHEDULE

3. DISTRIBUTION / AVAILABILITY OF REPORT
Approved for public release; distribution unlimited.

4. PERFORMING ORGANIZATION REPORT NUMBER(S)
MTR-10330
ESD-TR-88-262

5. MONITORING ORGANIZATION REPORT NUMBER(S)

6a. NAME OF PERFORMING ORGANIZATION
The MITRE Corporation

6b. OFFICE SYMBOL *(If applicable)*

7a. NAME OF MONITORING ORGANIZATION

6c. ADDRESS *(City, State, and ZIP Code)*
Burlington Road
Bedford, MA 01730

7b. ADDRESS *(City, State, and ZIP Code)*

8a. NAME OF FUNDING / SPONSORING ORGANIZATION
Deputy Commander (continued)

8b. OFFICE SYMBOL *(If applicable)*
ESD/AVP

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
F19628-86-C-0001

8c. ADDRESS *(City, State, and ZIP Code)*
Electronic Systems Division, AFSC
Hanscom AFB, MA 01731-5000

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO	WORK UNIT ACCESSION NO.
	6250		

11. TITLE *(Include Security Classification)*
Application of Modular Building Block Databus to Air Force Systems -- Final Report

12. PERSONAL AUTHOR(S)
Brayer, Kenneth

13a. TYPE OF REPORT
Final

13b. TIME COVERED
FROM ________ TO ______

14. DATE OF REPORT *(Year, Month, Day)*
1988 June

15. PAGE COUNT
38

16. SUPPLEMENTARY NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
Modular Building Block

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

Modular Building Block is a packaging concept for U.S. Government Systems that have shelterized implementations. In this final report of an investigation of its application to Air Force Systems, a brief description of the databus of Modular Building Block is presented along with a summary of the Modular Control Equipment, a current Air Force shelterized system development. A discussion is then presented on the applicability of Modular Building Block to Air Force Systems. While no suggestion of revising the Modular Control Equipment is made, application to future systems is proposed.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT
☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION
Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL
Pamela J. Cunha

22b. TELEPHONE *(Include Area Code)*
(617) 271-2844

22c. OFFICE SYMBOL
Mail Stop D135

8a. for Advanced Decision Systems

ACKNOWLEDGMENTS

This document has been prepared by The MITRE Corporation under Project No. 6250, Contract No. F19628-86-C-0001. The contract is sponsored by the Electronic Systems Division, Air Force Systems Command, United States Air Force, Hanscom Air Force Base, Massachusetts 01731-5000.

This paper presents the D-41 Modular Building Block Databus Study. In this paper, we review the technology of Modular Building Block and Modular Control Equipment and draw conclusions on the potential application of the former to Air Force Systems. Much of the discussion of Modular Building Block is taken from documents prepared by The MITRE Corporation but published by the Defense Communications Agency (DCA).

We acknowledge the author, David R. Israel, of DCA, J. Dominitz and his staff at MITRE, and Tom Sellers and his staff at Sandia National Laboratories who prepared the original material.

We also acknowledge Richard Platcow and Shelton Turner and their staffs at MITRE, and again Tom Sellers and his staff at Sandia, all of whom spent many hours in bringing us up to date on the subject of Modular Building Block.

Likewise, much of the material on Modular Control Equipment is taken from MITRE project reports.

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SECTION 1

BACKGROUND

In support of the Air Force World-Wide Military Command and Control System (AFWWMCCS), The MITRE Corporation has been asked to examine the Modular Building Block (MBB) concept developed by the Defense Communications Agency (DCA) with the objective of determining if there is potential application to Air Force systems.

While MBB is well known at MITRE and much of the prototype hardware is being developed at our Bedford, Massachusetts, location in support of the MITRE project office in McLean, Virginia, it is not extensively known within AFWWMCCS Planning.

AFWWMCCS Planning does have in-depth knowledge of various Air Force Command and Control Systems, such as the Ground-Launched Cruise Missile (GLCM) and the Small Intercontinental Ballistic Missile (Small ICBM) and can make a judgment as to whether or not MBB could have a favorable impact on the life cycle costs of such systems.

As a starting point, we are examining the MBB databus to see if it, or something like it, could be useful in "shelterized" Air Force Command and Control systems. After this examination is complete, a recommendation could be made as to whether or not the Air Force's Electronic Systems Division (ESD) either should pursue a more extensive attempt to bring MBB technology into future developments or should retrofit existing systems.

SECTION 2

INTRODUCTION

MBB is a concept that is currently embodied in specific designs implementing different classes of fixed and transportable electronic systems, e.g., strategic/theater, mobile/tactical, and intelligence. DCA, in association with The MITRE Corporation and Sandia National Laboratories, is developing demonstration systems for various customers.

MBB is a standardization and packaging approach that, as a goal, is promised to be independent of specific systems or mission equipment. The primary objective as stated by the DCA is to be able to implement and, hopefully, later retrofit a wide range of command, control, communications, and intelligence (C^3I) systems from a compatible set of standardized functional elements or modules, e.g., shelters, workstations, and cabinets.

The standardization is primarily emphasized at the equipment cabinet level, with the cabinet being the basic modular building block. A shelter or fixed facility is implemented by installing and interconnecting a series of cabinets. These elements are interconnected and can communicate over a databus that accommodates a wide variety of signal and control information and, hence, can be used to implement remote monitoring and control of the modules. Computer assistance is available for these processes.

Cabinets are independent of the shelter, permitting cabinets to be filled, assembled, and checked out by multiple sources and allowing integration and checkout to take place outside the confined space of a shelter. Later, replacement of entire cabinets can be implemented without a major effort.

The MBB concept does not attempt to standardize on specific types of electronic equipment, communication equipment, automatic data processing (ADP), terminals, etc. The concept relates only to the packaging and interconnection of these items in a way that focuses on their interchangeability by virtue of standard physical and electrical interfaces.

SECTION 3

MODULAR BUILDING BLOCK HARDWARE

The standard MBB cabinet is an enclosed equipment rack that provides 60 decibels (dB) of high-altitude electromagnetic pulse (HEMP) shielding. The cabinet has exterior dimensions of 24 inches in width, 30 inches in depth, and 82 inches in height. The interior height is 66 1/2 inches. The 24-inch width permits incorporating a standard Electronic Industries Association (EIA) 19-inch rack, with extra width to assure adequate air flow. The depth was selected at 30 inches to accommodate commercially available equipment; this results in two parallel rows of cabinets in the MBB shelter separated by a 30-inch aisle.

The cabinet sits on a base that provides a section of the air conditioning duct. Lighting and power junction boxes are also part of the cabinets, making it possible for cabinets to be largely independent of either the building or shelter in which they are placed.

The front door is latched and the rear panel is removable. Two versions of the cabinet are available: a full-door version, and a split-door version with an interior TEMPEST shield forming two compartments for use with COMSEC equipment.

MBB shelters are 8 feet by 8 feet in cross section and available in lengths of 13 1/2 feet and 20 feet. The cross section is the same as the standard ISO shipping container. The shorter MBB shelter is slightly larger than an S280 shelter; the 20-foot shelter is similar in size to an ISO container. Three 13 1/2-foot or two 20-foot shelters can be carried on a C130 aircraft.

Conventional shelter construction techniques are used. To maintain the integrity of this protection, penetrations of the sidewalls are not permitted but are restricted to the end sections, which are fully removable. One end section is for personnel entry and also provides air flow for environmental control units located just inside that end section. The other end section contains the penetrations for power, signal, and antenna connections, together with the necessary HEMP and TEMPEST filters and power distribution capabilities; it can be customized, if required, for specific systems.

The MBB shelter end sections are fully removable, to facilitate loading of the cabinets, and to permit end-to-end coupling of the shelters to obtain longer lengths.

Equipment cabinets are installed on either side of a 30-inch aisle. Environmental control units (ECUs) are located adjacent to the entry end section. With 30-inch deep cabinets and 30-inch aisles, it is possible to open a cabinet door and slide out a drawer for servicing, but it is not possible to remove a cabinet from the shelter via the aisle.

Power for the electronic equipment in either shelters or fixed facilities can be provided by commercial sources or towed power generation units. The radio frequency (RF) cabling from receivers and transmitters to external antennas runs under the false floor of the shelter to the electronic end section. Antennas and their cables can be carried in the center aisle of the shelter during transport.

A key component of the MBB architecture is a databus that minimizes the inter-module and intra-shelter wiring by multiplexing together all control and signal data (figure 1).

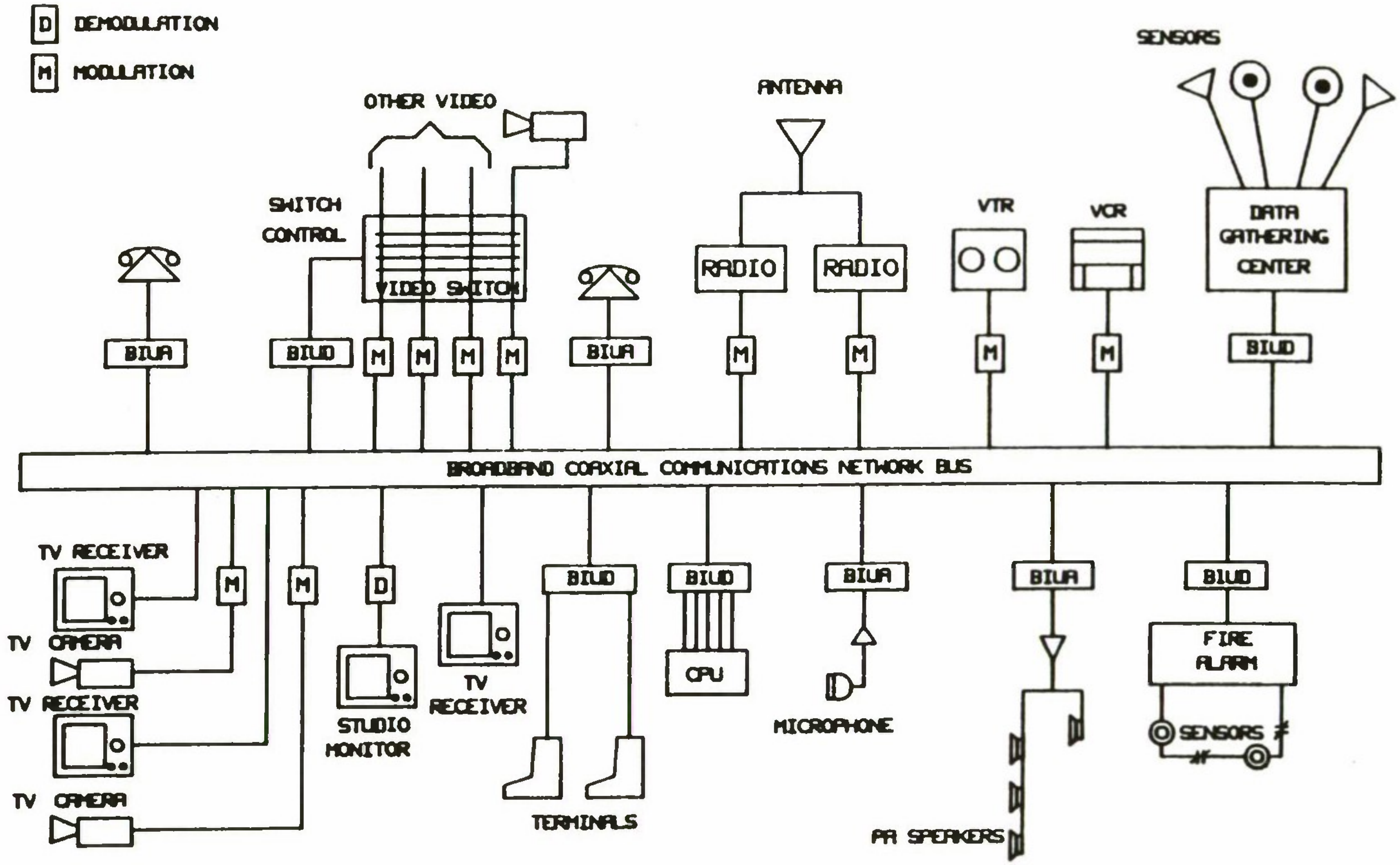


Figure 1. MBB Broadband Bus

The selection of an MBB databus design was governed by two principal objectives: first, to provide sufficient information capability for any foreseen application, and second, to accommodate the maximum number of different signals and formats to include the following:

- audio (both voice and modem tones)
- synchronous digital data
- asynchronous digital data (as with COMSEC equipment)
- video
- various vendor local area networks (LANs) (e.g., Ethernet, Wangnet)

In this design, a number of channels or circuits are created by frequency division multiplexing. The databus is implemented on coaxial cable and many channels can be created in the 300-400 megahertz (MHz) available; the number of signal channels depends upon the bandwidth assigned to each. Time division multiplexing may then be used within a channel to provide packet service channels or further signal multiplexing. Bus interface units (BIUs) are used to route signals on and off the databus. This is shown in a general implementation in figure 2.

Remote control and monitoring of devices on the databus is accomplished with device adapter modules (DAMs), microprocessor-based units that provide the correct electrical interfaces. Generally, it is necessary to design a DAM for each type of device placed on the databus, but future equipment is expected to have this interface capability built in. See figure 3 for an example of DAM utilization.

A typical MBB application might use a red databus and a black databus to separate classified and unclassified information. In such a case, radios and other external communications are generally connected to the black databus, while local communications and ADP equipment are connected

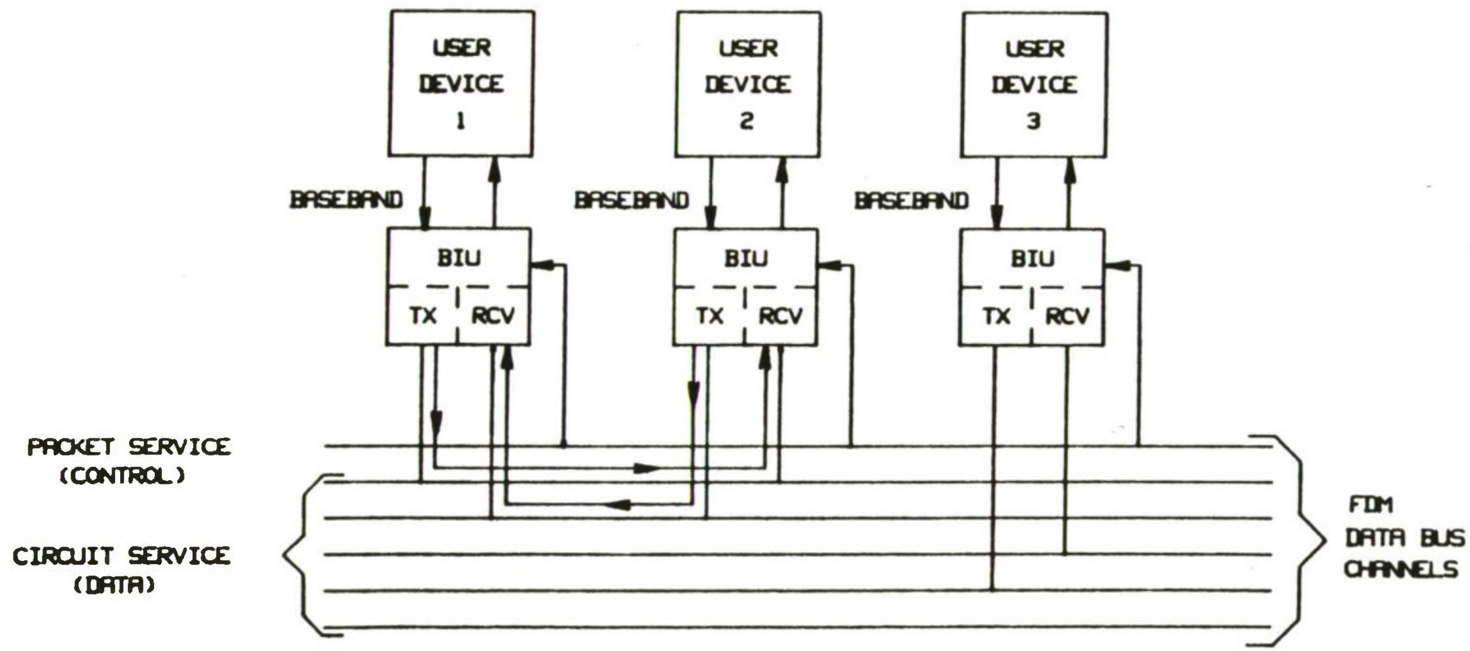


Figure 2. Bus Interface Unit Application

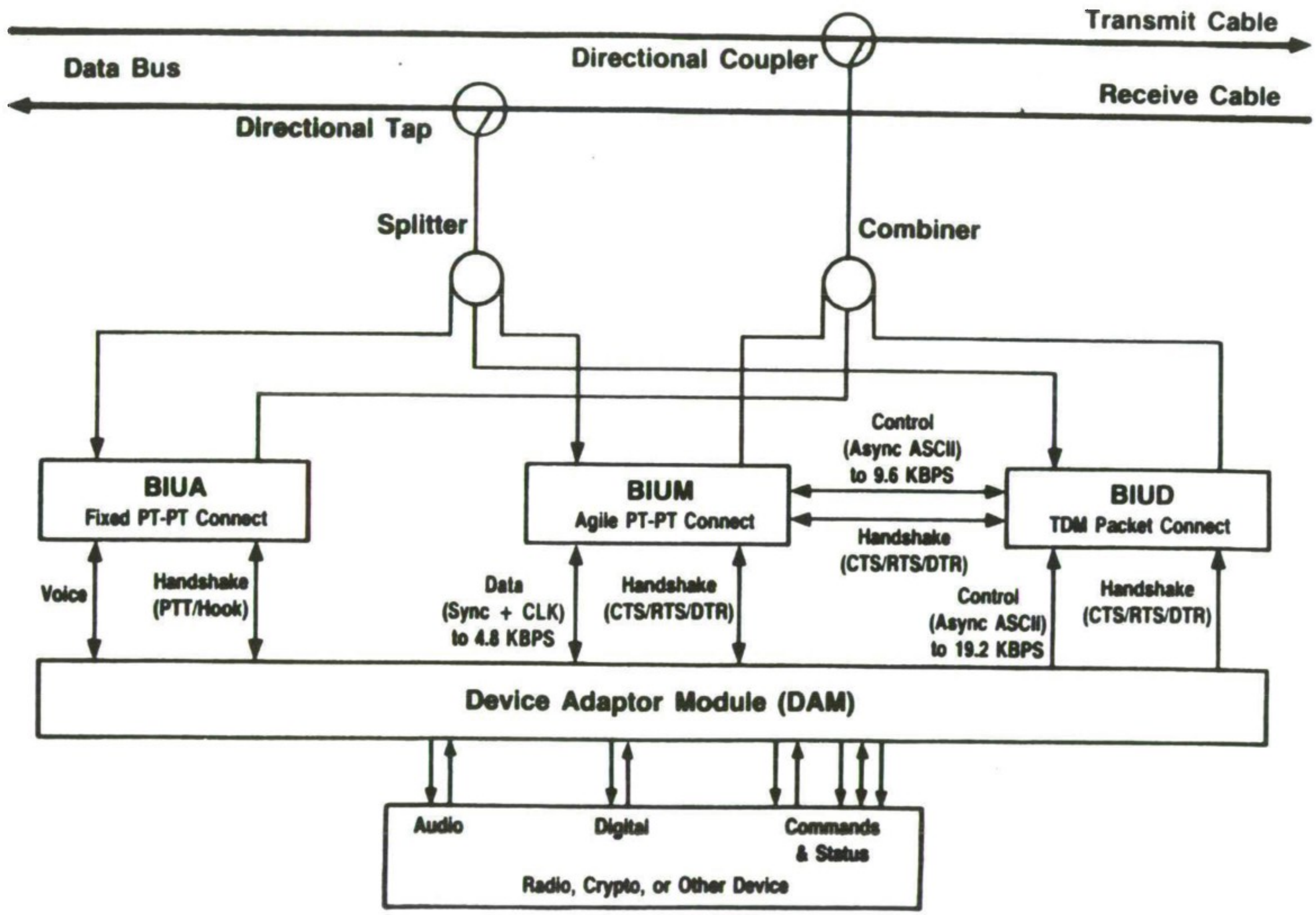


Figure 3. Dam Utilization in MBB

to the red databus. Located between the two databuses is the computer supporting the technical control position (figure 4) as well as COMSEC units. These units are controlled by the technical control position and are switched to the appropriate communication channels through the databus rather than being hard-wired. The databus also services all workstations and shelters.

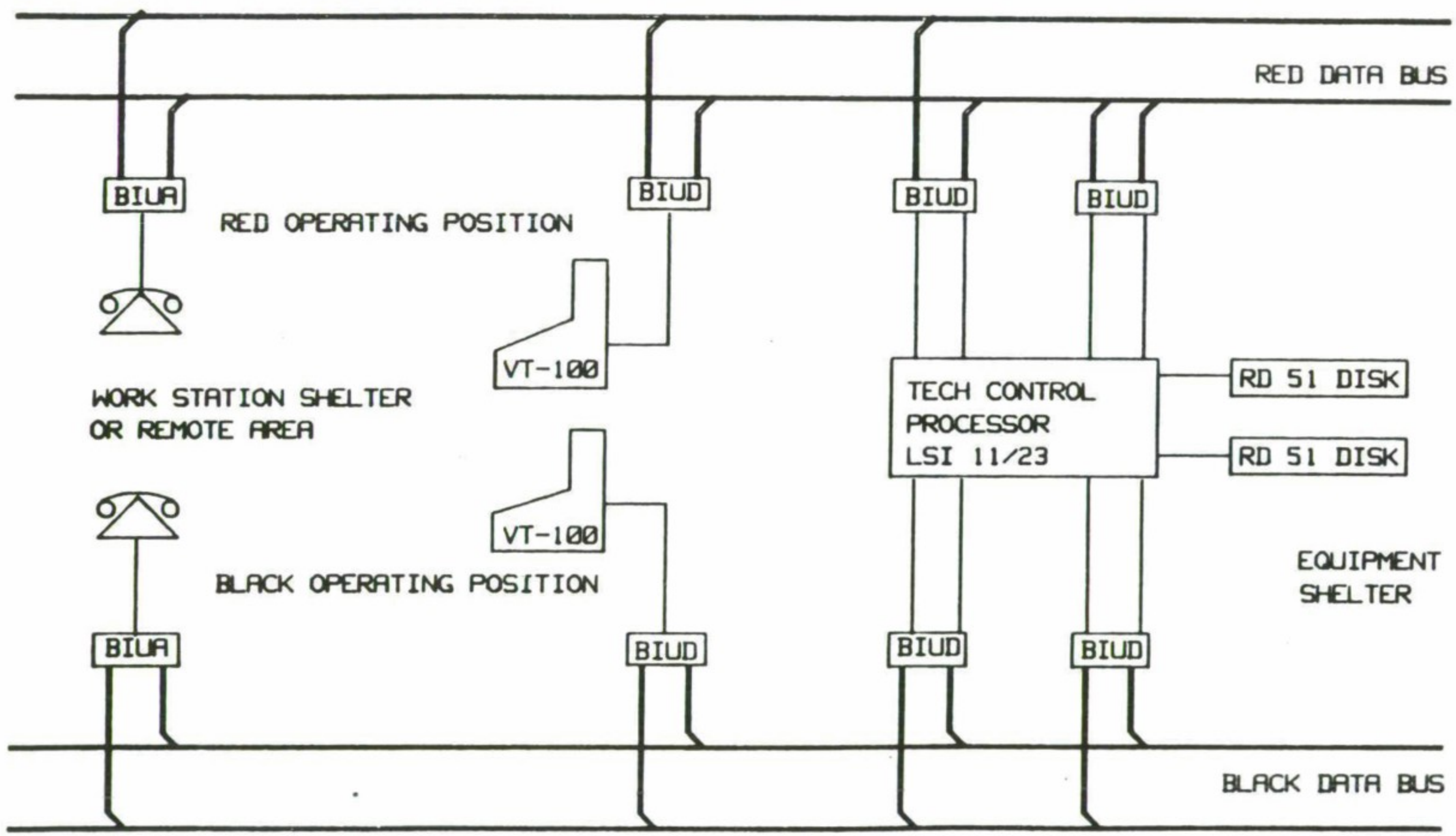


Figure 4. Technical Control Location

SECTION 4

THE DATABUS

A broadband databus offers advantages in that a single coaxial cable plant will provide connectivity for a variety of different types of circuits, including digital, audio, and video. Other advantages include a flexible and easily understood topology and the availability of commercial cable television hardware. Additionally, several different communication protocols can share a common communication media.

The normal MBB implementation consists of a red databus supporting unencrypted classified information, and a black databus supporting encrypted classified and unencrypted unclassified information. An example of this dual cryptographic bus is shown in figure 5. Attached to the red databus are sources and sinks of classified or unencrypted data such as ADP equipment, physical security and environmental monitoring equipment, a private branch exchange (PBX), and user workstations. Attached to the black databus are all of the external communications equipment such as high frequency (HF) or other types of radios, SATCOM terminals, and a PBX for landline terminations and internal black telephone or audio connections. Either type of databus can be used independently if the particular application only requires one type of connectivity.

The red and black databuses are bridged by various kinds of encryption devices for both voice and data. There is no data flow between the buses other than through these encryption devices. Also connected to both buses is the technical control processor. It does all digital circuit connections and control functions on both databuses, but does not process any data. The software and hardware are configured to ensure that there will never be an information link between the databuses.

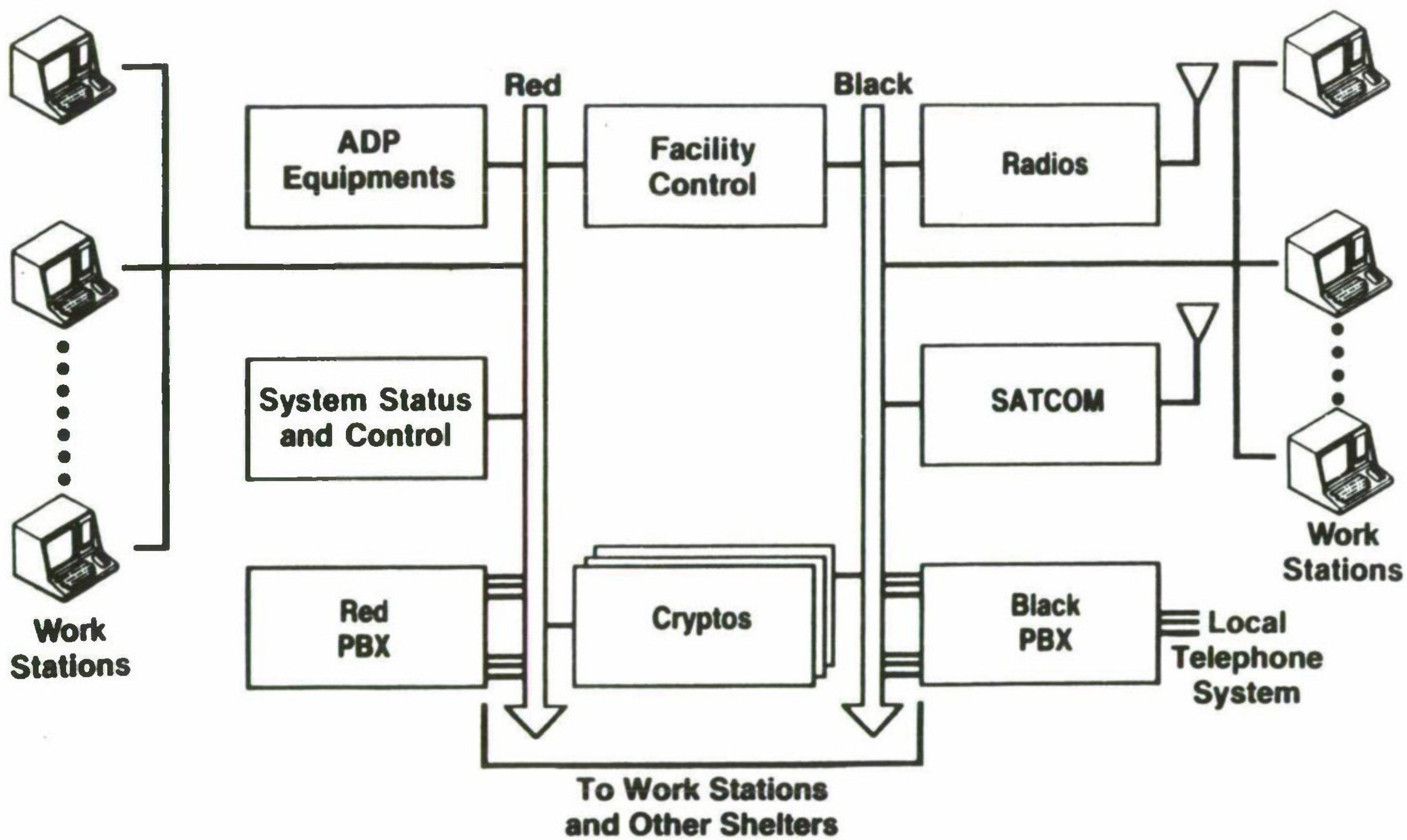


Figure 5. Dual Cryptographic Bus

The databus supports the transmission of several types of information such as byte-formatted digital data, unformatted digital data, audio or modem tone, and video.

Formatted digital data is asynchronous eight-bit bytes with start and stop bits, internally clocked at a standard baud rate, usually ASCII characters. Typically, communications between terminals or processor-to-terminal, at data rates of up to 19.2K baud, are considered to be formatted. This is also includes all control functions transmitted on the databus.

Unformatted or arbitrarily formatted digital data is usually digitized voice or the output of encryption devices. However, it also includes non-standard format synchronous data, Baudot data, and isochronous or externally clocked asynchronous data.

Audio information is any analog signal with a frequency bandwidth consistent with standard telephone equipment. This is usually analog voice or modem tones.

Video signals are supported on the bus using standard cable television (CATV) modulators and tuners. This includes a capability for broadcast monitoring as well as local camera monitoring or point-to-point conferencing.

The databus also supports other standard commercial protocols such as Wangnet, DECnet, or Ethernet. A commercial network and a telephone T1 link have been implemented on the databus.

Several types of generic BIUs are used to handle various data formats on the databus: the BIU digital (BIUD) for formatted digital data; the BIU modem (BIUM) for unformatted or arbitrarily formatted digital data; and the

BIU audio (BIUA) for audio data. Also, there are currently two specialized BIUs available, one to support a special commercial network and one to support a T1 link on the databus.

The formatted digital data BIU (BIUD) is based on the Net 20 System developed by and available from Sytek, Inc. Net 20 is designed to link many ASCII protocol devices from 1 to 20 databus channels in a single 6 MHz TV channel on the databus. Each BIUD supports a full-duplex virtual circuit with another BIUD on the same channel, and is transparent to the user once the virtual circuit is established. Each BIUD maintains its operating parameters in battery backed-up memory; therefore, on powerup, each BIUD is properly initialized for use. These parameters include user interface settings such as baud rate, EIA handshaking conditions, number of stop bits, and databus access information such as unit ID and channel number. These BIUDs do not retain session connections; therefore, on powerup, individual virtual circuits need to be established by the technical control processor.

The BIUD contains an RF modem and a logic and control board. The RF modem is tunable over 20 channels within a 6 MHz frequency band. It modulates the baseband logic board output on the RF carrier and demodulates the input from the carrier for the logic board. The logic board processes the RS-232C user input. It does the packetizing and collision detection functions for the Carrier Sense Multiple Access with Collision Detection (CSMA/CD) packet-channel protocol as well as the channel control of the modem card. Two RS-232C user ports are available on each BIUD logic board and multiple logic boards may be used with a single modem board, depending on the needs of the system.

BIUAs are fixed-frequency point-to-point audio modems. Because they are fixed frequency, they are intended to operate in pairs between a PBX and a telephone or telephone-equivalent device. They support standard telephone features and capabilities including on/off hook, ring signaling,

and dialing. They also have special features such as the capability to transmit press-to-talk control signals and, therefore, are transparent to the user. On/off hook and ring are provided by subaudible tones. User-to-user connectivity is provided by the PBX.

There are two different forms of the BIUA that make up a link pair, one for the PBX connection and one for the user-device connection. A BIUA will support either a two- or four-wire connection to the PBX. The choice is generally made on the basis of how the user can indicate on/off hook to the PBX. A radio or crypto usually does this external to the audio circuit and requires a four-wire connection. All telephone features are supported normally except ring, which is a separate output of the BIUA. The BIUA does not provide the voltage level necessary to ring the normal bell, so a "sonalert" or buzzer supplies the audio ring indicator.

Another special feature is the capability for a public address (PA) circuit. This feature requires a second receiver in the BIUA and a special transmitter-only BIUA at the PBX.

The arbitrarily formatted databus interface-unit modem (BIUM) supports a point-to-point link using frequency-agile RF modems. A BIUM link is capable of transferring a single data stream at up to 100K baud. Two modem pairs are necessary to support a full-duplex link, one operating in each direction. Because there is no packetizing or processing of the data stream such as with the BIUD, a BIUM link is totally transparent to the users. BIUM links are also used for circuits where timing is critical, such as externally clocked crypto outputs. Each RF transmitter and receiver is frequency agile to allow full connectivity among user devices.

Control of the agile modems is from the databus via a BIUD. Each BIUM channel requires a transmitter, a receiver, a user interface, and a control board. The control board individually tunes the transmitter and receiver

according to commands received via the BIUD link. As implemented, a control board can tune up to six sets of transmitters and receivers. The data interface consists of the necessary line drivers and receivers to connect user devices.

A typical interface between two devices consists of data, clock, and handshaking. A special data interface is available to expand the number of channels supported by a single BIUM. This interface uses time division multiplexing (TDM) to carry four independent signals over one BIUM channel, allowing data, clock, and handshaking to be supported. However, when using the TDM interface, the data speed is limited to 4.8K baud.

BIUs are built with standard RS-232C BIUD, RS-423 BIUM, or telephone-level BIUA interfaces. Many devices that one would like to connect to the databus are not designed with compatible interfaces. For example, either the control inputs may not be serial ports or the software language may be different. To overcome this limitation and to standardize the databus, a DAM is used. The DAM provides a hardware and software interface between the BIUs and the unique needs of the user device.

On the databus, frequency channels are allocated to users in groupings compatible with the 6 MHz channel definitions of cable television.

The cable plant is a dual cable, branching tree topology. One cable carries the signal from the BIUs to the headend (return) and the other carries the signal from the headend to the BIUs (forward). The cable is quad-shielded RG-59 for short lengths and CD-7040 for longer lengths.

The headend consists of a frequency translator and an RF amplifier. The frequency bands of 69.2-79.1 MHz and 94-100 MHz are translated by 156.25 MHz. This is the standard mid-split LAN frequency translation; all other frequencies are not translated. RF filters are used to separate the

translated from the untranslated frequencies. Both frequencies are amplified and retransmitted on the forward cable.

SECTION 5

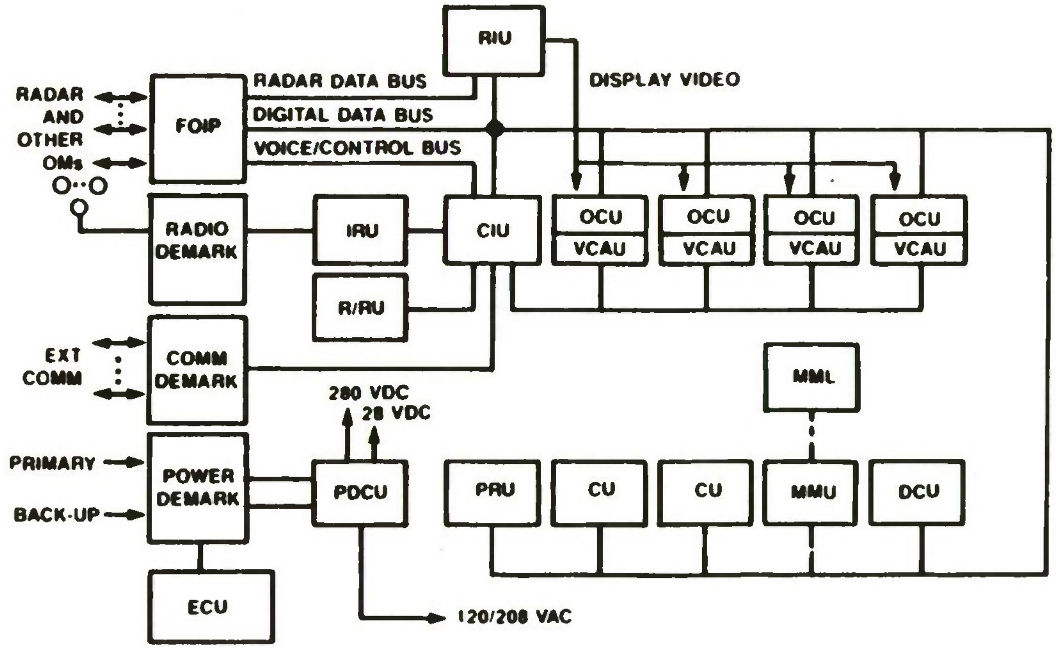
MODULAR CONTROL EQUIPMENT

Modular Control Equipment (MCE) is a transportable, modularized, highly-automated command and control system capable of controlling aircraft in offensive and defensive air operations. The system is being developed to replace parts of the present 407L Tactical Air Control System (TACS). The basic system module of the MCE is the AN/TYQ-23 Operations Module (OM), which is housed in a standard 20-foot ISO shelter. From one to five OMs can be configured to form a tactical field unit. Generally, two OMs will be used for a Forward Air Control Post (FACP) and four OMs for a Control and Reporting Center (CRC). The MCE Interface Group (MIG) which is housed in the AN/TPS-43E Radar, also constitutes a part of the MCE. The MCE is a USAF-modified version of the USMC Tactical Air Operations Central - 1985 (TAOC-85).

The deployment of MCE hardware can vary in size from a single OM interfacing with up to 3 radars to a 5-OM system interfacing with up to 4 radars, each of which includes an MIG. Each system uses three buses, figure 6, to provide a mechanism for communicating and passing data among units within an OM and external to that OM. These buses are the Digital Data Bus (DDB), the Voice Control Bus (VCB), and the Radar Data Bus (RDB).

MCE provides digitized communications between OMs and the radars/MIGs using three separate bus networks: DDB, VCBN, and RDB. For a multi-OM system, the OMs are connected in a fiber optic star topology that simplifies the echeloning requirements of MCE where an OM may be added to the system or removed from it at any time without disrupting any operations. For reliability, the star topology utilizes a redundant bus. Since a single OM is not used as the hub for both the primary and secondary bus, a

Operations Module Architecture



CIU	Comm Interlace Unit	MMU	Mass Memory Unit
CU	Computer Unit	OCU	Operator Console Unit
DCU	Digital Comm Unit	PDCU	Power Distribution and Control Unit
ECU	Environmental Control Unit	PRU	Printer Unit
FOIP	Fiber Optic Interface Panel	RIU	Radar Interface Unit
IRU	Internal Radio Unit	R/RU	Recorder/Reproducer Unit
MML	Mass Memory Loader	VCAU	Voice Comm Access Unit

Figure 6. Operations Module Architecture

more reliable and survivable system is obtained. Therefore, if a failure occurs at an OM, the remaining OMs may not be affected.

The DDB and VCB share the primary and secondary buses making the most use of the available wires or fibers per cable. The DDB/VCB use fiber optic cables between OMs. These cables have no electromagnetic emissions and are not susceptible to electromagnetic interference (EMI). Fiber optic cables are lighter to transport as compared to the same length of metallic cable, and using full-duplex rather than half-duplex communication between OMs simplifies the star coupler design required.

The DDB passes digital data at 10 Mbps among the users within the same OM. The DDB also incorporates a function for evaluating the integrity of the inter-OM communications. The VCB, on the other hand, just passes digitized voice at 16.4 Mbps from one CIU in an OM to another CIU in a different OM. For a Voice Communications Access Unit (VCAU) operator in an OM to communicate with a VCAU operator at the MIG, another bus is required. This bus, the Radar Data Bus, provides a Radar Voice Channel (RVC), which has a 128 kbps data rate, to support the above situation. The communication path between an OM VCAU operator and the Radar VCAU operator may include using the VCB in addition to the RVC if the OM operator is in a different OM from where the RVC is terminated. When the VCB is used to complete the communication path, it is transparent to the operators. A breakdown of the Voice Communications System structure is given in figure 7.

The RDB also has two other channels for transmitting digital radar data and digitized video at 10 Mbps to the OM from the MIG. Because both channels transmit identical information to the OM, there is redundancy built into the system. This redundancy also improves the survivability of the system by passing the redundant information on to a second OM via a passive coupler in the first OM. Thus, if the first OM (where the RDB link

MCE Voice Communications System

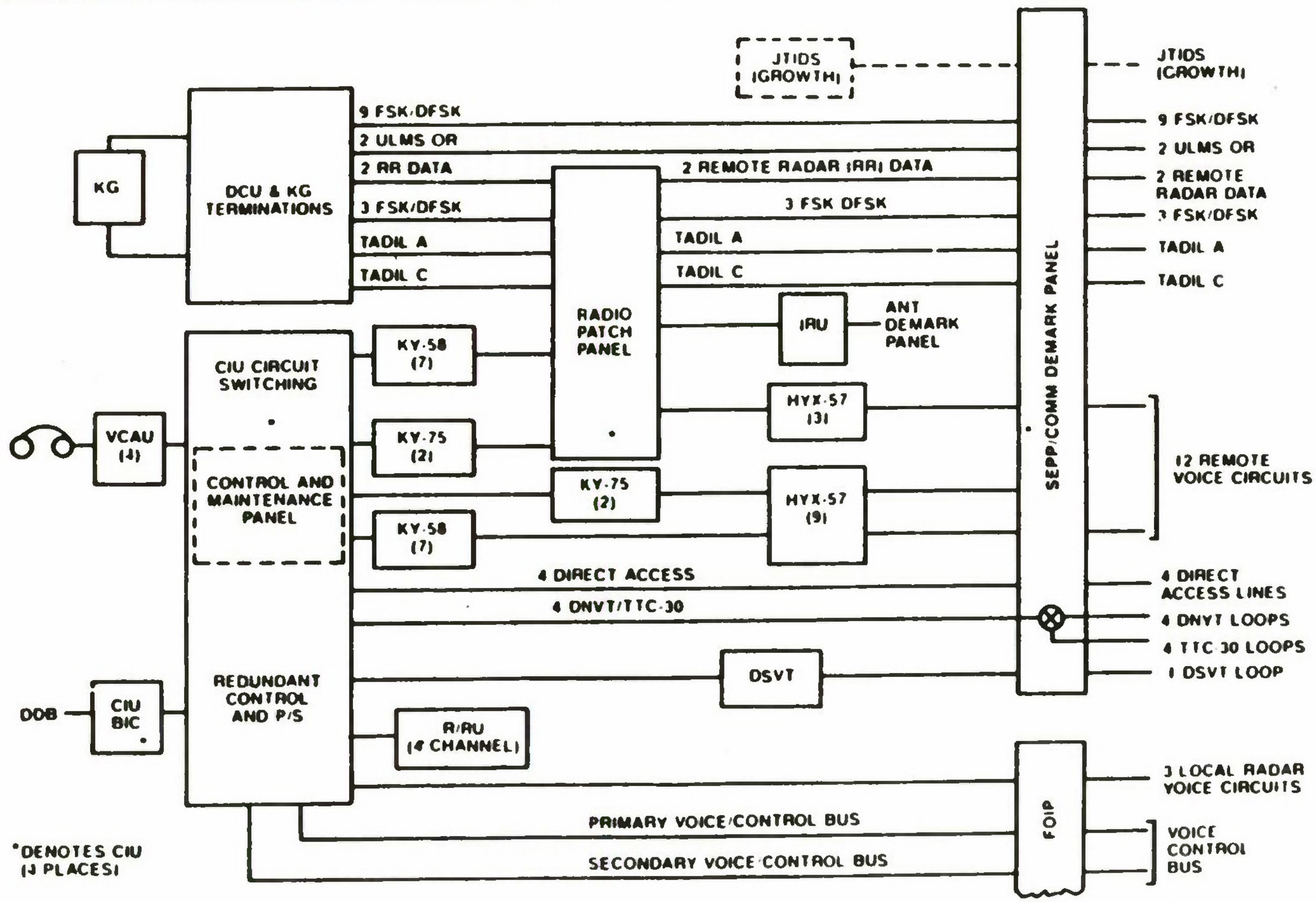


Figure 7. MCE Voice Communications System

is terminated) has a failure, the second OM can still process and use the radar data and video information. However, in the event of a casualty in the first OM (i.e., the OM is damaged or destroyed), the ability to pass redundant information to the second OM may be hindered or not possible. For clarification, redundancy in the RDB is for the radar data and video only. Consequently, if a failure occurs at the OM terminating the RDB link, voice communications over the RVC between the OM and the MIG are lost.

So that the other remaining OMs in the system may maintain the status of a particular radar, the radar data and video from the "nonredundant" channel are distributed to the remaining OMs via a distribution coupler (e.g., 1:3 combiner/splitter). In the case of a single OM system, the same bus structures apply but are simplified by not having to distribute information to other OMs.

SECTION 6

MODULAR CONTROL EQUIPMENT DATABUSES

Three system buses are employed in the MCE. All buses use a star network topology to connect up to five OMs. The transmission media for the buses are shielded twinax cable within the OM and fiber optics cable between OMs and to the local radars. Access by an MCE hardware unit to any bus is through some form of microprocessor-controlled bus interface unit or line termination unit.

The DDB connects hardware units (CUs, OCUs, DCUs, etc.) of all OMs that require exchange of digital data. The DDB uses a fixed sequency "listen-to-talk" protocol that allows any unit to transmit if the bus is quiet. The protocol works as follows:

1. A unit waiting to transmit listens via its bus interface controller for traffic on the bus.

2. If the bus is quiet, the waiting unit transmits.

3. If the bus is active, the waiting unit inspects the active message on the bus for the sequence number of the transmitting unit. From this number, the waiting unit computes the delay required to permit any other waiting unit with a lower sequence number than its own to start to transmit. If after this delay the bus is quiet, the waiting unit transmits. If not, the process starts over.

Design permits the DDB to operate even if units are disconnected from the bus. The DDB is redundant by means of a primary and secondary bus.

Units normally transmit on both buses simultaneously. A switchover to the secondary bus means to switch receivers only. A unit can transmit several messages each of up to 526 32-bit data words in one access to the DDB.

Design of the DDB allows expansion to accommodate eight OMs.

The VCB connects voice communications units (VCAUs, radios, telephones, etc.) of all OMs for exchange of voice data. The VCB also provides control to the operator for remote channeling of UHF radios and for remote control of the voice crypto units. The front panel layout of the VCAU is shown in figure 8. The VCB uses a TDM protocol which works as follows:

1. Time is divided into frames of 125 microseconds each frame.

2. Each of 200 units that can be on the VCB, 40 per OM, is assigned a time-slot for digitized voice data at a fixed position in the frame. This time-slot is approximately 0.5 microseconds long.

3. Each unit can transmit or receive 8 bits during its time slot every 125 microseconds.

Design permits the VCB to operate even if units are disconnected. Like the DDB, the VCB is redundant by means of a primary and secondary bus.

Voice Comm Access Unit Front Panel

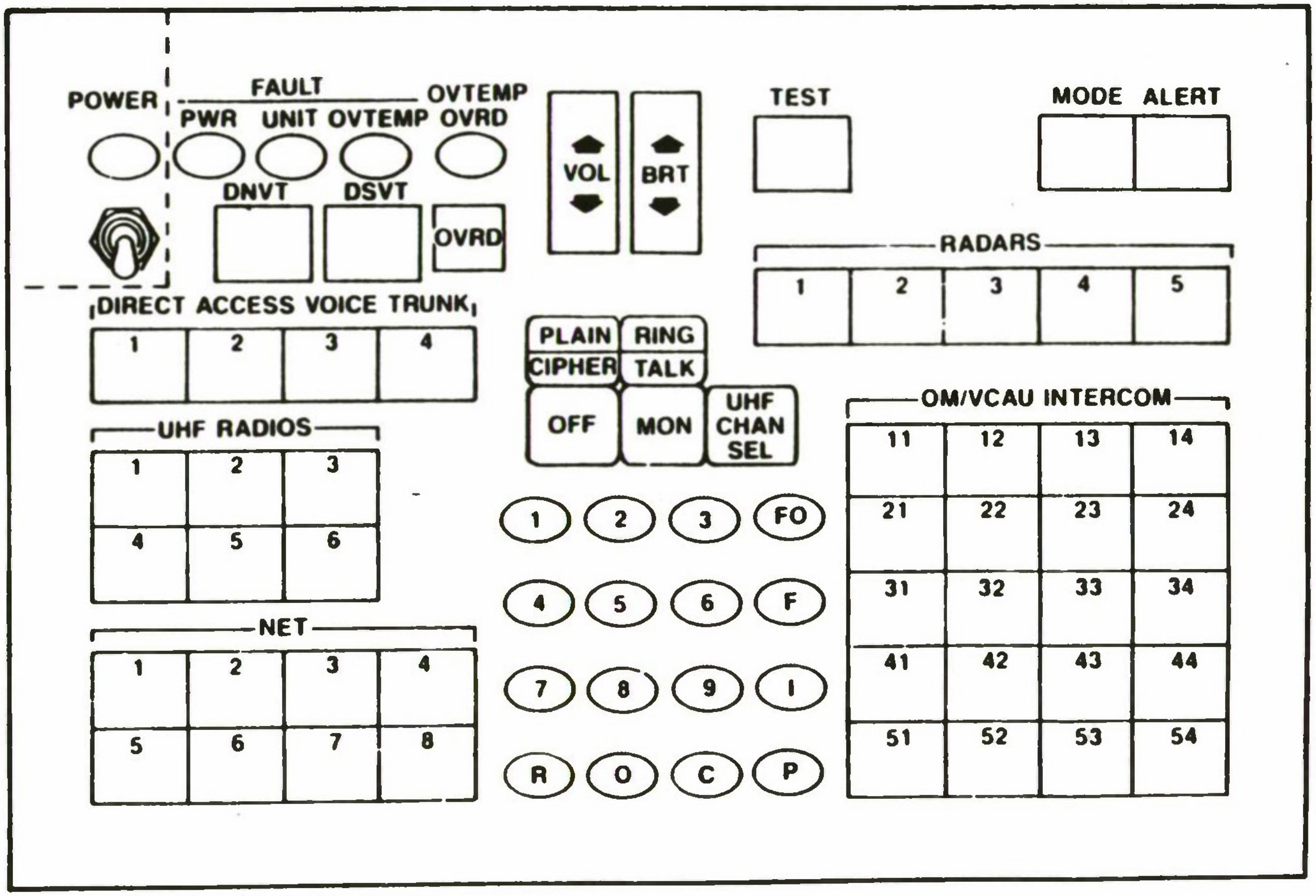


Figure 8. Voice Comm Access Unit Front Panel

SECTION 7

COMMENTS ON MBB APPLICATION TO MCE AND FUTURE AIR FORCE SYSTEMS

In this paper we have reviewed the structure and design of MBB and its databus and we have examined the features of the MCE, a current shelterized system development.

The MCE is a multi-shelter system using up to five standard 20-foot ISO shelters with cabling between them. In some applications a system like this might be able to take advantage of the modular concept and its standard racks for moving equipment between shelters or directly connecting shelters. Movement of equipment into and out of the MCE shelters is not as easy as in MBB. Similarly, the positioning of workstations is more flexible in MBB than MCE.

MCE uses three buses, each for a distinct purpose. These buses handle data for various applications and system management. MBB has only one bus. This may seem more efficient, but the MBB bus capacity is less than that of MCE. The MCE is, however, near the limit of its capacity while the MBB bus structure can expand to handle more data on the channel. MCE, being a specific user system, was designed to meet a given set of user requirements and cannot exceed them without being accused of waste. If a modular system were used, fear of such an accusation would be avoided.

Through the use of multiple shelters in a star configuration, MCE probably gains a great deal of redundancy which could be costly to reproduce in MBB.

One thing this author had previously experienced in a tour of the Ground Launch Cruise Missile (GLCM) Command Shelter was the use of a bus

for many command features but not for control of many of the various radios on that shelter. The MCE controls its radios via one of its buses and this is certainly an aid to its operations. MBB does the same thing via the various BIUs and DAMs.

In summary, the MCE is a fine example of what can be done using a bus architecture and I see no reason to suggest changing it over to an MBB design. It is, however, limited in some ways and overly complicated in others because it is a special purpose design. The MBB approach could relieve this problem in future system designs. MCE actually does many things that are envisioned in the MBB concept. It is clear from this author's study of MCE, and knowledge of GLCM and other C^3 system components such as Communications Nodal Control Element (CNCE), that MCE has gone a long way to solve many of the problems of equipment interaction in traditional shelterized systems. MCE does, however, represent a unique design. If new system developments continue in its direction, there will be use of all the latest features of technology including bus structures, each one unique with costly duplication of effort and manufacturing and attendant increases in the cumulative budgets of these projects. It seems only reasonable that as many as possible of the features that are not in the most rapidly moving parts of technology should be standardized in perhaps 15-year evolving timeframes.

It is concluded that very serious consideration should be given to employing MBB in future systems. The advantages should be quantified by a cost comparison study taking an actual existing system such as MCE. MCE could then be compared to other such systems to develop a complexity comparison and an estimate of the total scope, and complexity of systems in the 15-year timeframe could be extrapolated. A total cost impact of not using MBB could then be projected.

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GLOSSARY

Acronyms

ADP	automatic data processing
AFWWMCCS	Air Force World-Wide Military Command and Control System
ASCII	American Standards Committee International Interchange
BIU	bus interface unit
BIUA	BIU audio
BIUD	BIU digital
BIUM	BIU modem
CATV	cable television
COMSEC	communications security
dB	decibels
DCA	Defense Communications Agency
ECU	environmental control unit
EIA	Electronic Industries Association
ESD	Electronic Systems Division
GLCM	Ground-Launched Cruise Missile
HEMP	high-altitude electromagnetic pulse
HF	high frequency
ICBM	Intercontinental Ballistic Missile
ISO	International Standards Organization
LAN	local area network
MBB	Modular Building Block
MCE	Modular Control Equipment
MHz	megahertz
PA	public address
PBX	private branch exchange
RF	radio frequency
SATCOM	satellite communications
TDM	time division multiplexing